BlueFinder

Final Presentation

DEVELOPMENT TEAM

Stefan Crigler

PCB design, software help, team lead

Robert Tremewan

PCB design, software help

Renny Hong

software design, RF/DSP

Arthur Lobins

software design, RF/DSP

Cynthia Alvarez

software design, Fusion/UI

BlueFinder is a prototype hardware/software platform that enables limited-range direction tracking of Bluetooth devices without requiring any additional information.

OVERVIEW

- Building on last year's capstone project BlueDentist, which captured Bluetooth packet information
- Locate Bluetooth devices using XTRX software defined radios (SDR) programmed with direction-finding algorithms

POTENTIAL APPLICATIONS

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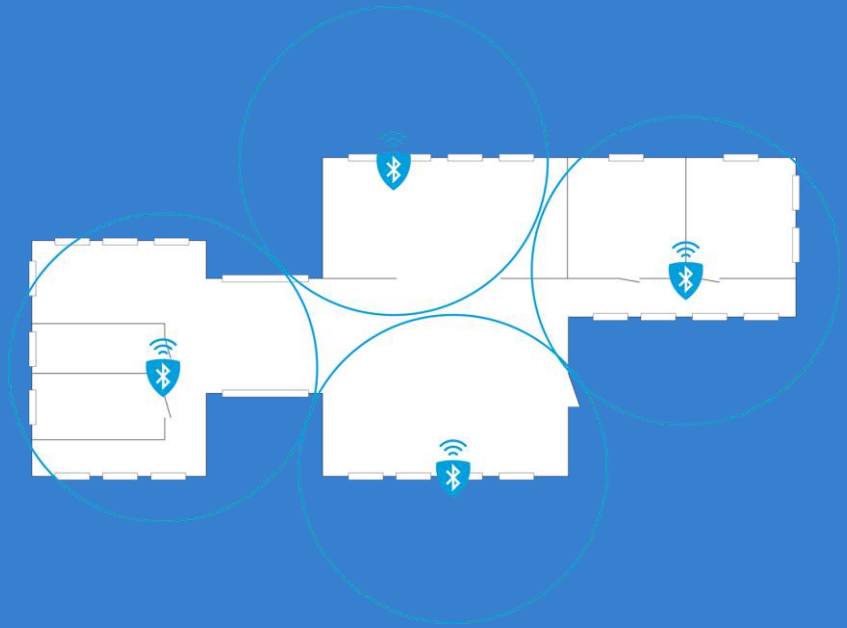
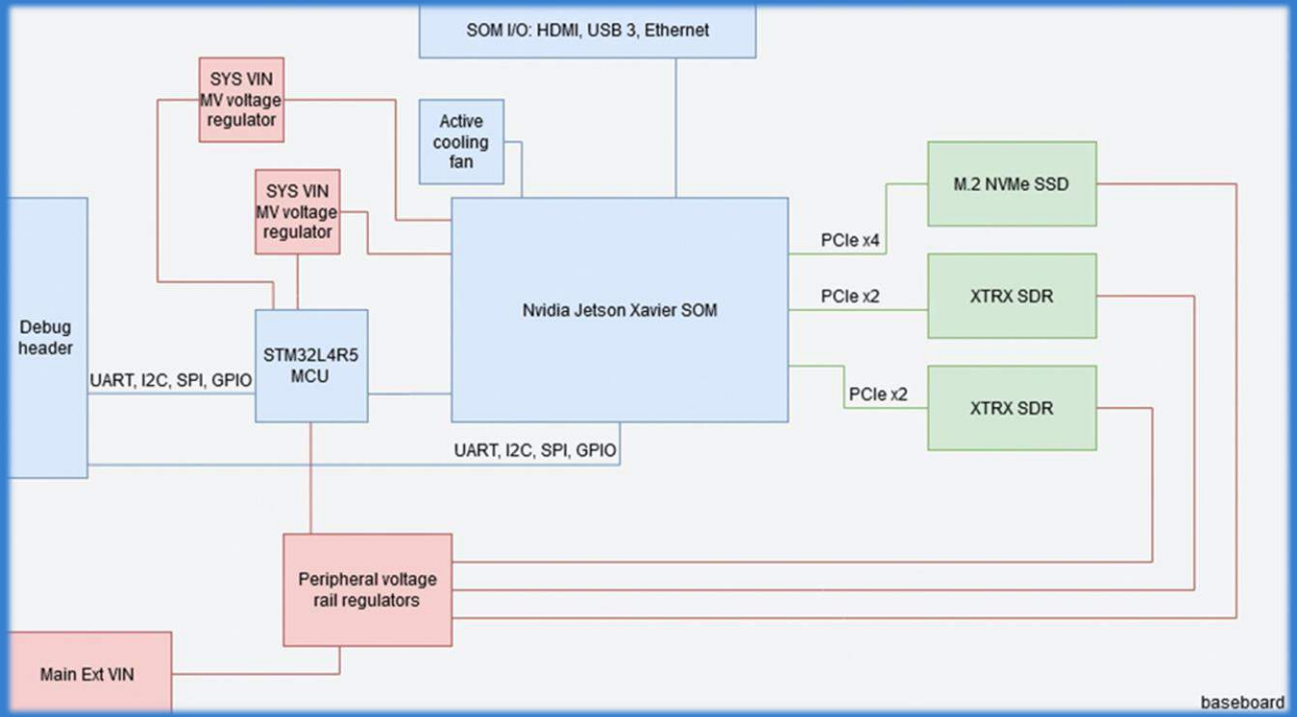
Tracking and analysis of ad-hoc gatherings of customers in a restricted location

Tracking, tallying, and management of workers or assets in a workplace



BLOCK DIAGRAM



- STM32 controls power
- XTRX SDR send raw direction data to Jetson

KEY HARDWARE

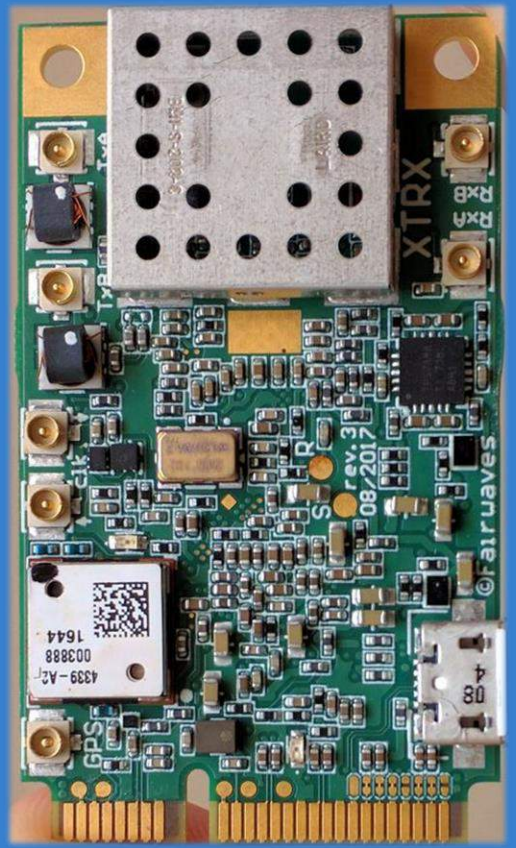
Nvidia Jetson AGX Xavier

- Runs the software which processes the raw data coming in from the radios
- Software was developed on the devboard version while the custom PCB was developed

KEY HARDWARE

XTRX

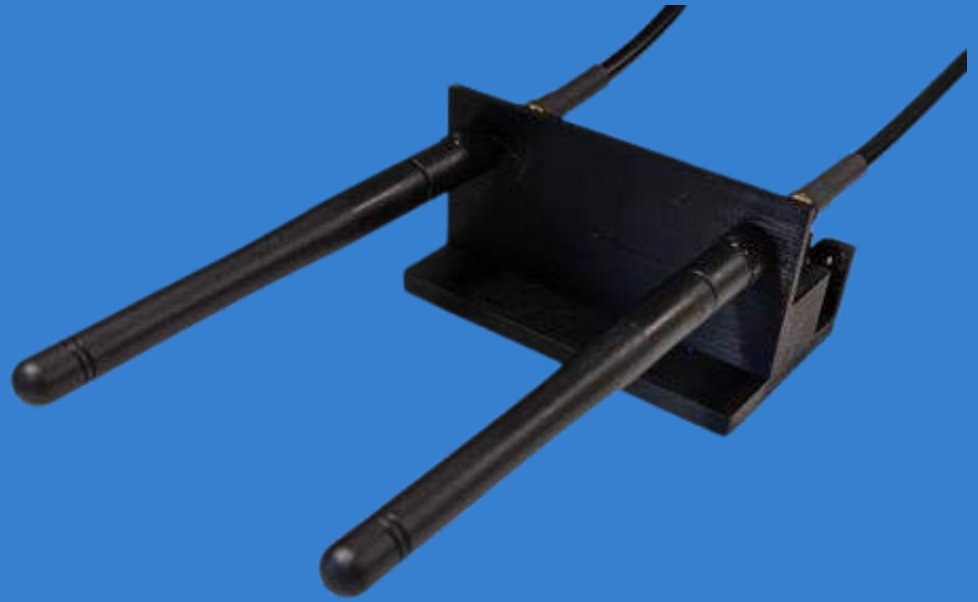
- Software-defined radio programmed to listen on the Bluetooth frequencies around 2.4GHz
- We have two on the board for up to four potential antennae, however only one was used in our current setup



KEY HARDWARE

Antenna Assembly

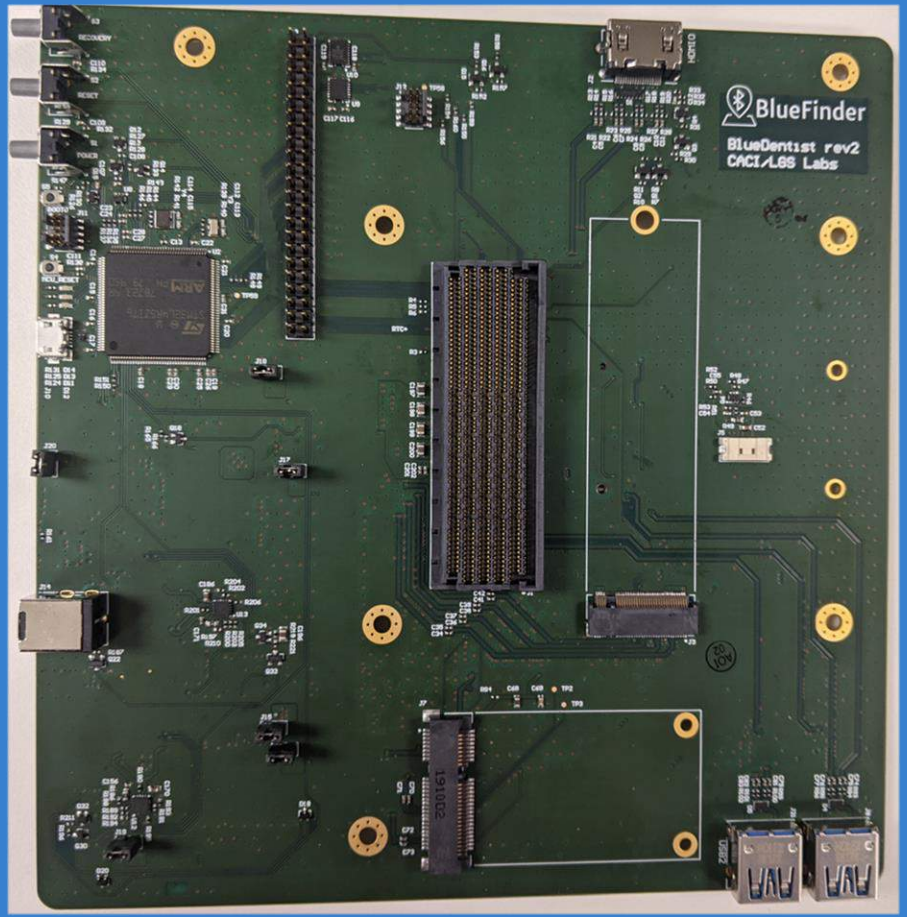
- In order to position the antennas exactly as required we had to design and 3D print a set of mounts
- 6.5 cm apart, fixable positions for consistent antennae positioning



KEY HARDWARE

Revision 2 PCB

- We needed an extra PCIe slot to accommodate both SDRs so we had to revise the board designed by the BlueDentist project last year



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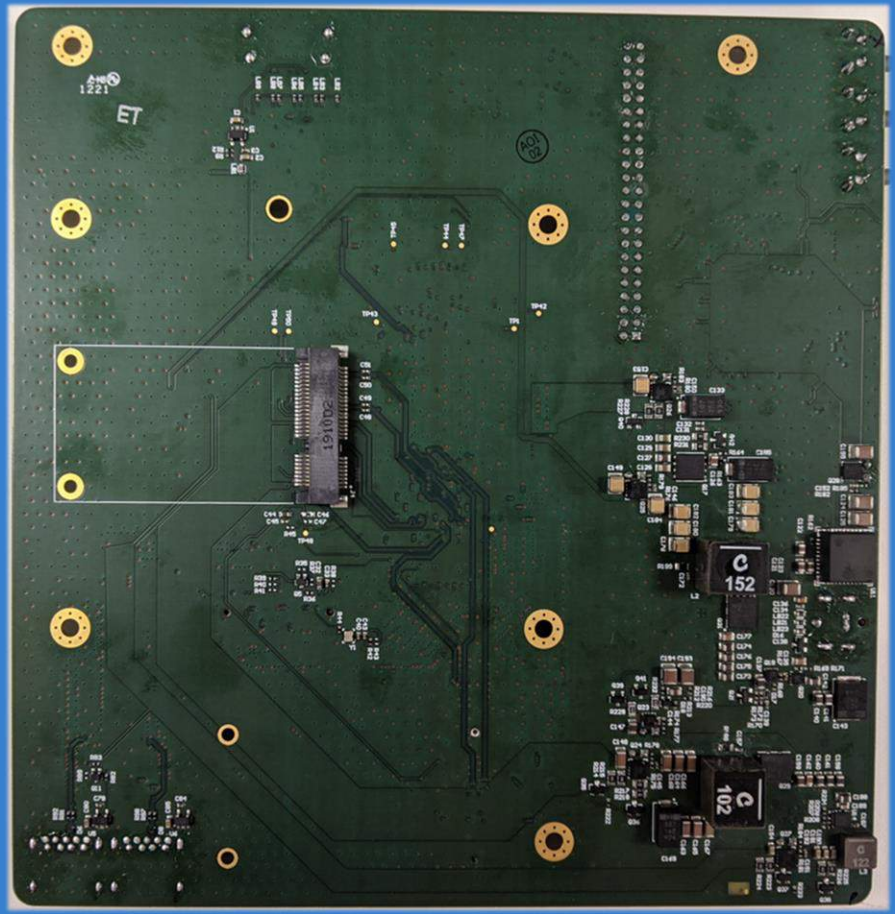
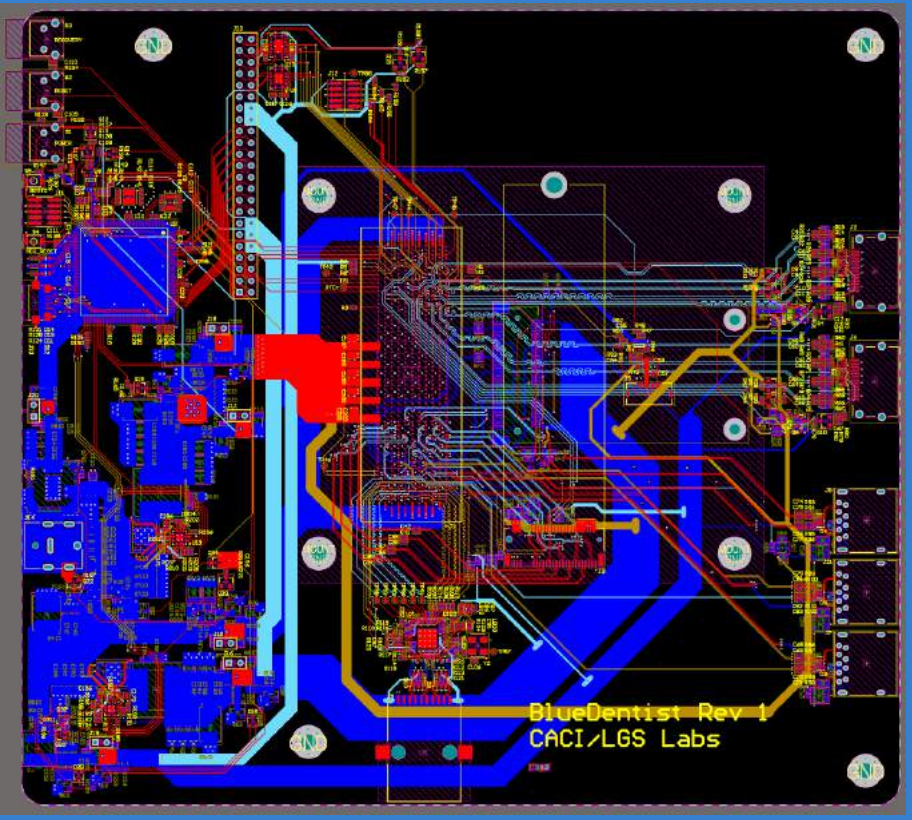
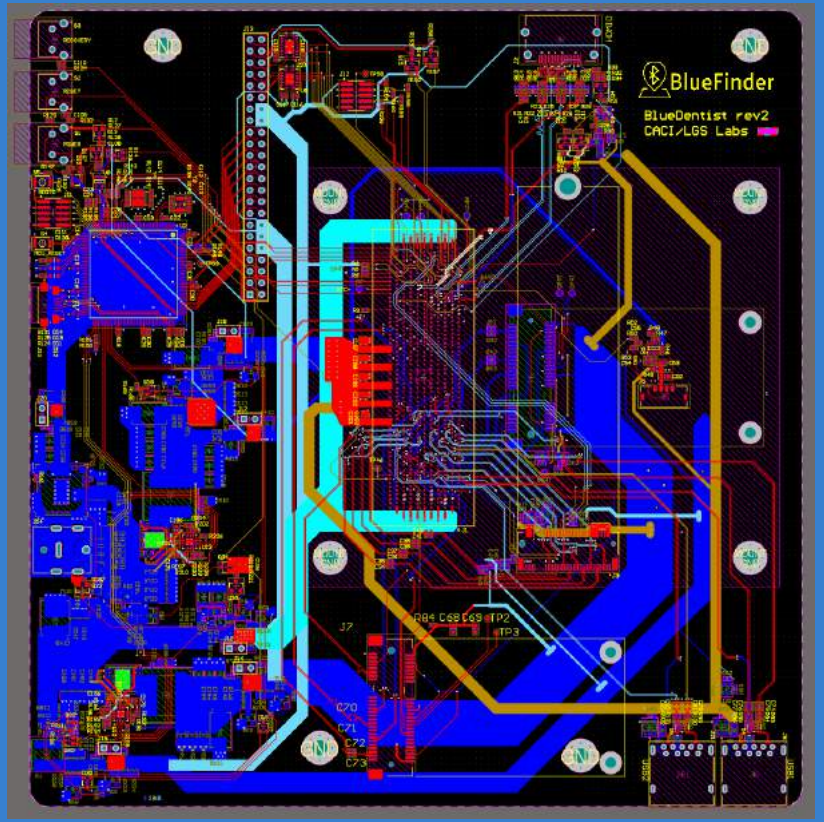


Revisions compared

OLD



NEW

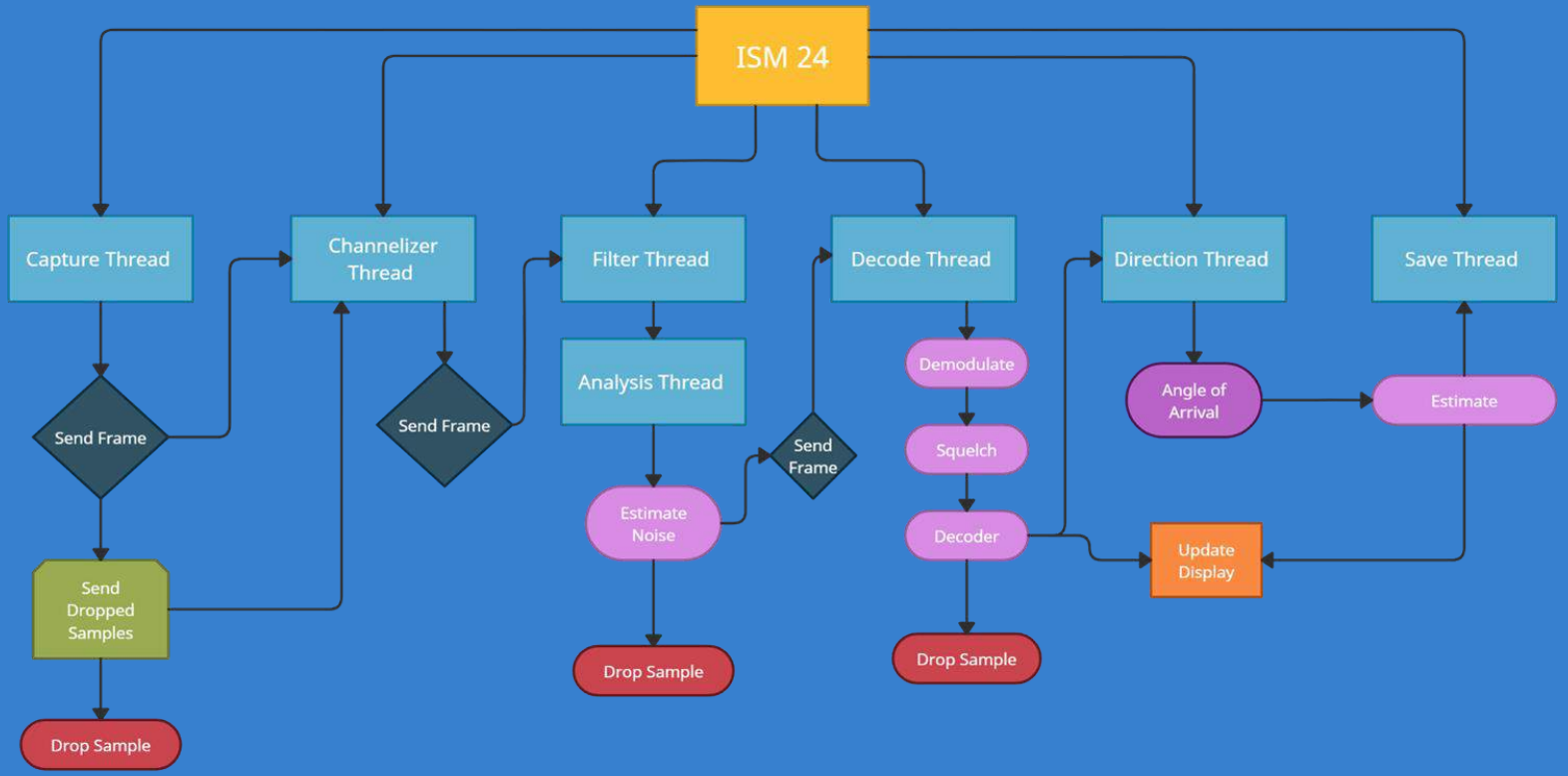


Revisions compared

OLD

NEW

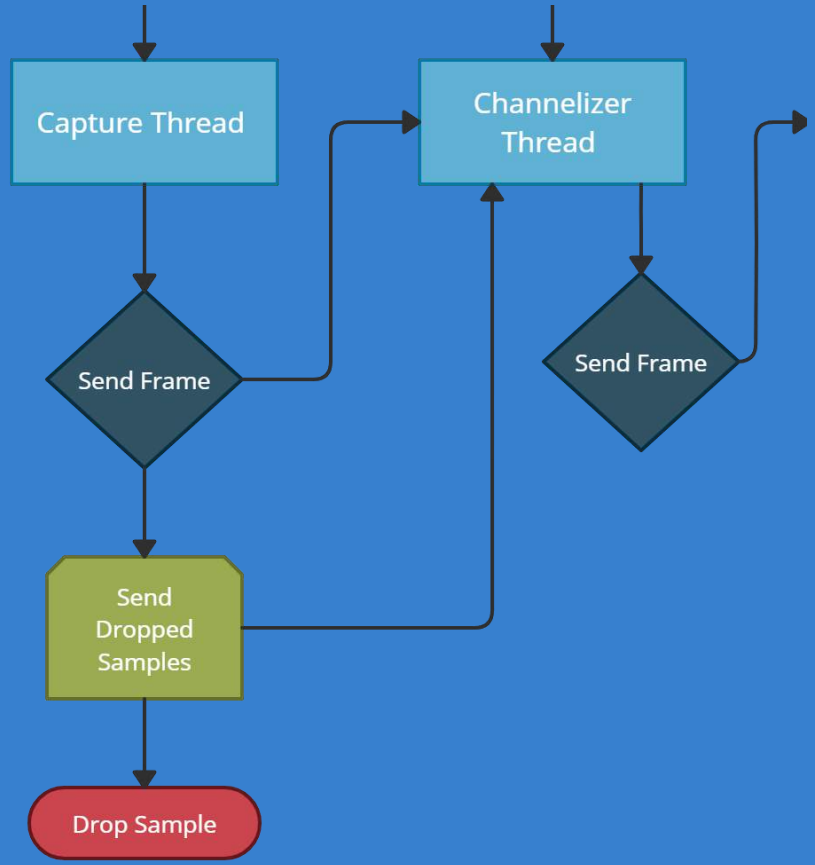
SOFTWARE FLOW DIAGRAM



SOFTWARE FLOW DIAGRAM

Capture and Channelizer Threads

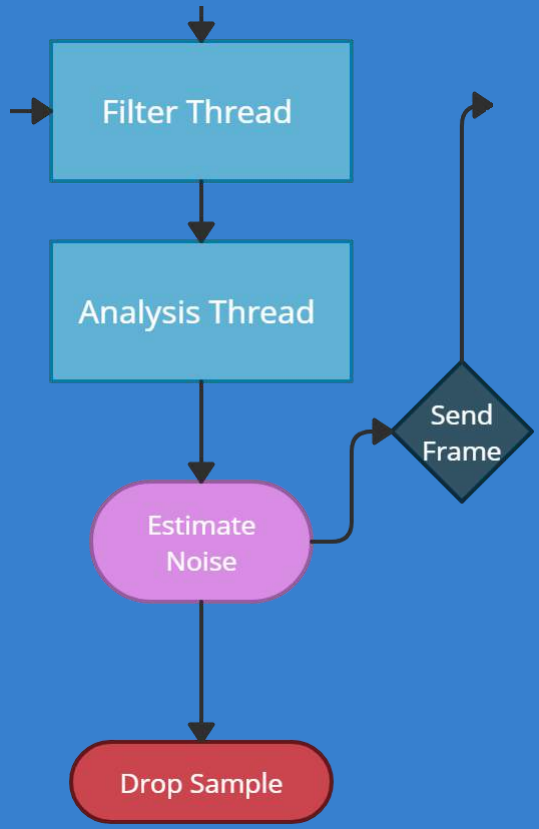
- The Capture Thread is where we adjust the radio configuration such as sample size and frequency
- The captured data is placed into a frame, which acts as a buffer for complex 16-bit numbers. If the buffer is full, some samples will be dropped, or sent along with the next frame
- A captured frame is then sent on to the channelizer thread, which splits the sample up into the 79 bluetooth channels



SOFTWARE FLOW DIAGRAM

Filter and Analysis Threads

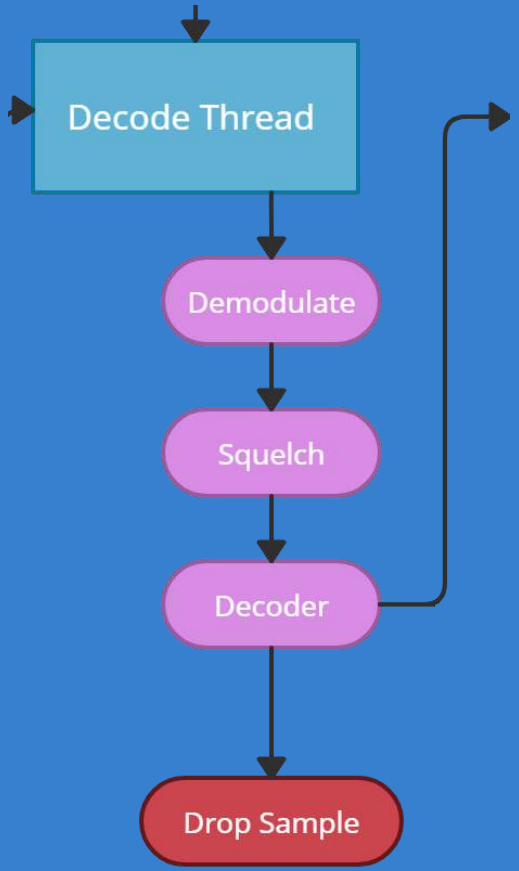
- The Filter thread determines the time selection of the frame that contains a Bluetooth signal
- The Analysis thread will calculate the channel power for the frame and estimate noise floor threshold
- If the power of the channel > noise threshold, then it is possible a Bluetooth device is in a channel



SOFTWARE FLOW DIAGRAM

Decode thread

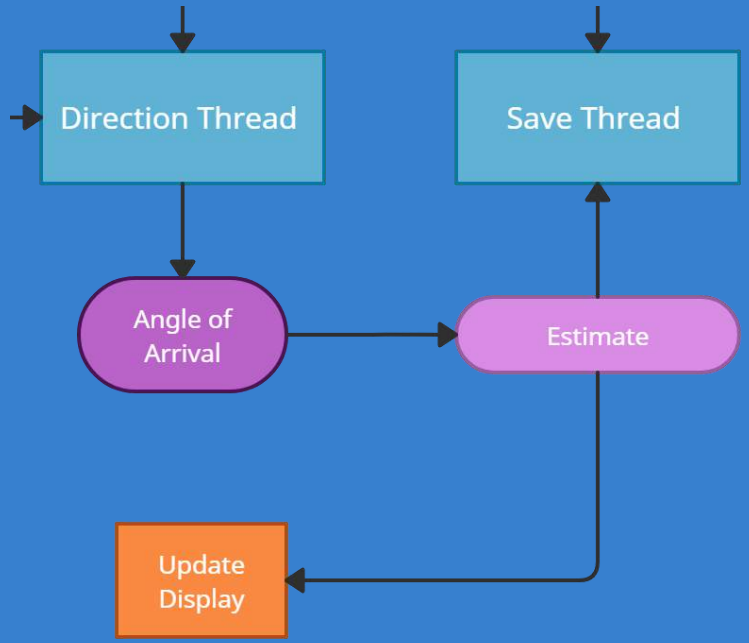
- If a frame potentially captured a Bluetooth signal, then it is sent to the decode thread, where the frame is decoded for a Bluetooth access code
- The access code is estimated based on the number of bit flips required in the capture frame to form a valid Bluetooth access code



SOFTWARE FLOW DIAGRAM

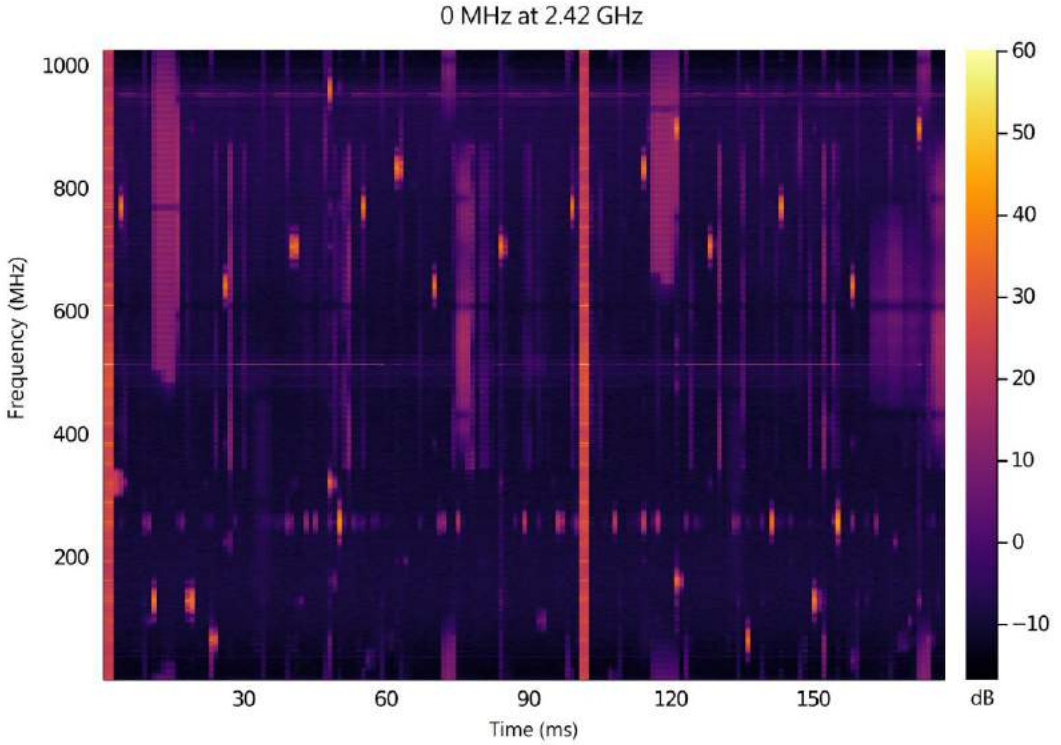
Direction and Save Threads

- If a frame is found to contain a Bluetooth access code, the frame is forwarded to the Direction Thread
- Calculates AoA estimation using MUSIC algorithm on the channelized frame
- Finally, data is saved locally on an SSD.



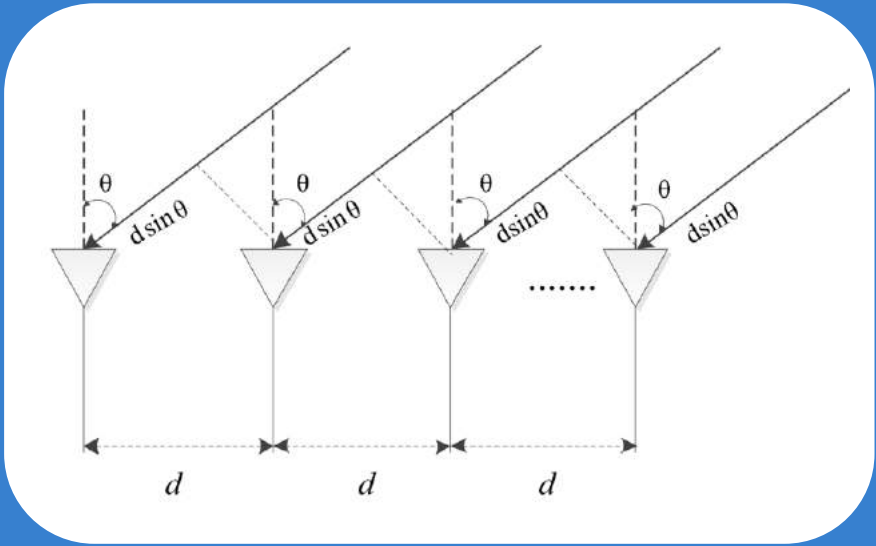
DATA COLLECTION

- Monitoring the 2.4GHz band for interesting bursts of signals
- The data is processed if it contains a Bluetooth signal under a certain noise threshold
- Interesting frames are decoded and used in our direction finding algorithm



ANGLE OF ARRIVAL ALGORITHM

- Linear array of antennas with known spacing
- The bearing angle to the signal source is determined using phase difference between the signals received by multiple antennas
- MUtiple SIgnal Classification Algorithm (MUSIC)
  - High Resolution
  - Possible to estimate AoA for multiple signals simultaneously



MUSIC ALGORITHM

- Estimate the autocorrelation matrix using an eigenspace method

1. Calculate sample covariance matrix
2. Eigendecomposition

    - Largest eigenvalues and corresponding eigenvectors span the signal subspace
    - The rest corresponds to noise space

- Signal vectors in the signal subspace must be orthogonal to the noise space

3. Generate complex sinusoids of various incident angles
4. Measure the level of orthogonality w.r.t. noise space

- Angle resulting in the highest orthogonality is the estimated direction of the signal source

UC **SANTA BARBARA**

College of Engineering

Thank you for your time!
Questions?